AN EXPERIMENT IN CULTURAL INTERPRETATION AND MAP REVISION FROM SKYLAB DATA

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INTRODUCTION

Skylab was an experiment involving a manned space platform that orbited Earth. The platform, called the Orbital Workshop (OWS) and designated SL/1, housed experiment hardware and astronaut scientists for extensive periods. Experiments were conducted by three separate trios of astronauts who accumulated diverse scientific data, traveling to and from the OWS in Command Modules SL/2, SL/3, and SL/4. The astronauts took unexposed film and fresh recording tape and returned to Earth with exposed film and tape. Multidiscipline experiments were conducted during the lifetime of Skylab. The Earth Resources Experiment Package (EREP) had relatively low priority, but nevertheless the three Skylab missions successfully photographed large portions of the Earth. This report describes sensors for cartographic applications and the specific use of S-190A and S-190B data for revision of small-scale maps in the United States.

RESEARCH PROPOSAL OBJECTIVE

The general objective was to determine if Skylab S-190 images could be used to revise small-scale maps (1:250,000 to 1:1,000,000) in the United States. Specific objectives of the proposal were:

1. To determine the degree of correlation between space image details and map culture details and to categorize the correlative types.

2. To attempt limited revision of one or more small-scale maps.
3. To determine whether presence or absence of leaves is more conducive to cultural interpretations.
4. To learn how Sun angle affects the quality of space imagery for cultural identification.
5. To learn the effects of atmospheric moisture and aerosols on culture identification by studying the imagery of arid, humid, and industrialized areas.

Limitation of data prevented us from addressing the last three objectives.

<u>Meaning of Revision</u>

Map revision means updating a map. In the U.S. Geological Survey (USGS) photoinspection is used to determine the obsolescence of 1:24,000-scale 7.5-minute quadrangle maps. A formula guides the photoinspector in deciding whether revision is warranted. The formula contains units of measure to apply to missing map features; major and minor features are considered separately.

For example, a major new feature, such as a mile or more of interstate highway with at least four lanes would warrant revision of the quadrangle or at least 5 miles/quad of new roads symbolized at the minimum 40-foot width, with no segment less than a mile long, would be a minor feature warranting map revision.

Other features with similar criteria are drainage, reservoirs (at least 1 mile long and covering at least 0.75 square mile), airports, strip mines, and new subdivisions or urban growth.

Small-scale maps do not have an appraisal formula since they are normally compiled from large-scale maps, revision depends directly on the revision status of the component larger scale maps. When the 7.5-minute quadrangles making up a 1:250,000-scale map (usually 128) have been revised, the 1:250,000-scale map can be revised.

The maps used in our experiment were standard line maps, graphic portrayals of planimetric or cultural features by means of symbols. Preparation and revision of satellite image maps was not an objective, but an experiment in combining a line map and photoimage is included as an adjunct.

Experiment Sites

Five experiment sites (fig. 1) in the United States were designated in the research proposal. They were separated geographically to provide diverse mapping conditions. An area in the populated eastern seaboard near Washington and Baltimore was selected as Area 1. Area 2 centered on Minneapolis-St. Paul was selected for the combination of climate, agriculture, and Sun angle. An area around Seattle was selected as Area 3 for conditions of climate, Sun angle and foliage. Area 4 around San Francisco has a wide variety of mapping conditions,

including the coastal zone, high-density urban population, and rural mountains. Area 5 in southern California and Arizona provided a test of mapping in an arid area with a high Sun angle.

THE EARTH RESOURCES EXPERIMENT PACKAGE

Skylab Sensors

The report is limited to the Multispectral Photographic Facility of EREP, which consists of the Multispectral Photographic Camera (MPC) and the Earth Terrain Camera (ETC).

Skylab Orbit

The Skylab OWS was launched in April 1973 in an inclined orbit that covered the area between the 50th parallels north and south every 5 days. The combination of orbital configuration and field of view of EREP sensors precluded Skylab from ever systematically covering the Earth as Landsat does.

Multispectral Photographic Camera (MPC)

The MPC, designated S-190A, was a precisely related array of 6 film cameras with an f/2.8 lens, variable aperture, and 6-inch focal length. The cameras were boresighted and shutter synchronized to record the same area simultaneously. Image format is 2.25 inches on 70-mm film. From an altitude of 435 km, the 21.2^{o} field of view provided ground coverage 163-km square at the scale of 1:2,850,000.

Earth Terrain Camera (ETC)

The ETC camera, designated S-190B, consisted of a single-lens camera with an 18-inch focal length. Different film and filter combinations were used at different times. Forward motion was compensated. A bidirectional focal-plane shutter was used, and stereocoverage was obtained with up to 60% forward lap. Image format is 4.5 inches on 5-inch film. From an altitude of 435 km, the 14.2° field of view provided ground coverage of 109-km square at the scale of 1:950,000.

Skylab Imagery

The separate cameras of the MPC, numbered 1 through 6, contained the same film-filter combinations on each mission. Cameras 1 and 2 always recorded on black-and-white infrared film. Cameras 3 and 4 recorded on color infrared and normal color films. Cameras 5 and 6 recorded on black-and-white panchromatic film.

Film positives, both 70-mm and 9-inch, from all six cameras were obtained for parts of all sites. The 1:2,850,000 scale of the 70-mm positives with 2.85X enlargements yielded a scale of 1:1,000,000 on the 9-inch positives.

For most of the photography both the MPC and ETC systems were active at the same time. The ETC records are not multispectral but restricted to the particular film/filter combination in use at a given time.

Data were obtained in winter and summer. Unfortunately the winter coverage was obtained when the ground was covered with snow, making photointerpretation of cultural features impossible.

The tables (fig. 5) reproduced from the Skylab Earth Resources Data Catalog show the characteristics and film rolls used for the MPC and ETC.

Relation of Data and Orbit Configuration to Experiment Sites

The 5 experiment sites covered areas as large as 7° N-S by 8° E-W. Before launch these sites had to be refined to only 2 specific but separate areas the size of a 1:250,000-scale quadrangle (1° by 2°), which became the prime target areas. The other 3 sites were then considered targets of opportunity.

Because of the footprint of Skylab imagery (i.e., the ground area covered by the sensors on a given pass) and the angle of inclination of the orbit, the area of a 1:250,000-scale quadrangle could not be covered in a single pass. In addition, the data were collected on both descending (NW. to SE.) and ascending (SW. to NE.) orbits, and since the satellite was not Sun synchronous, the cameras photographed continuously while passing over the Sun terminator on Earth. Thus photographs contain varying densities due to changes in scene illumination.

PROCEDURE

Selection of Experiment Quadrangle

Photography for revision sometimes follows the determination of a map's obsoleteness, and often the evaluation photographs are used for the revision. Although the areas were preselected for this experiment, the data received had to be analyzed for cloud cover, resolution of map detail, and general usability before a specific map could be considered for revision.

In addition to an obsolete map and the proper data, some type of check of the compilation was required. In normal revision the checking is omitted because the parameters of the photography are controlled so that photointerpretation is positive. For this experiment the obsolete map chosen had been updated by standard means so that the application of S-190 data could be checked. The map chosen was the Baltimore 1:250,000-scale quadrangle, which had been revised in 1969. The Chesapeake 4° by 6° quadrangle of International Map of the World (IMW) covering the same area was outdated and could be checked by referring to other maps of larger scale.

Map Materials

The reproduction materials used in color printing of the obsolete 1:250,000-scale map were combined on transpsrent film (Cronaflex) to form a blue-line composite. (The contours were omitted.) This transparent film is referred to hereafter as the overlay.

Photographic Materials

NASA supplied all 6 multispectral records in the form of film transparencies. For this experiment the SL-3 mission provided relatively cloud-free stereoimagery on May 8, 1973, at 10:00 a.m. EST, over the East Coast experiment site during a northwest to southeast orbit. The sharper black-and-white images were chosen over the color samples for photointerpretation. Imagery from cameras 2 and 5 (rolls 20 and 23) were used. Frames 193, 194, and 195 were enlarged using the existing map base as a control. Both black-and-white transparencies and paper prints were made with a rectifying enlarger, and no correction for tip or tilt was required as the images were essentially orthographic.

Revision Method

Cultural features are often revised monoscopically in USGS operations. A positive film transparency of the photograph is placed on a light-table; and a copy of the obsolete map, reproduced on a transparent material suitable for penciling (Cronaflex), is laid over the film transparency. Map features are added or deleted.

Stereoscopic observation was considered since this strip of imagery had been taken with 60% forward lap. Stereopairs at 1:1,000,000 scale on 9 by 9-inch film were oriented in a Kern PG 2 plotter. The compilation pantograph of this plotter is not designed for enlarging. Thus compilation is limited to the scale of the diapositives (1:1,000,000 or smaller) unless

the individual scene is segmented. The advantages of using the excellent magnifying optics and stereo at 1:1,000,000 scale were offset by the constraint of the small compilation scale, and therefore stereoscopic revision was not used.

Revision Problems

Small-scale maps are cartographically compiled from large-scale maps (as opposed to direct photogrammetric compilation). The large-scale maps are compiled from high-resolution aircraft photographs. During the cartographic compilation, some map features are judiciously discarded to avoid cluttering. Even so, more detail, such as secondary roads, streams, and limits of cities and towns, is shown on USGS 1:250,000-scale maps than can be seen in Skylab imagery.

In monoscopic revision when the transparent overlay containing many features is registered over the Skylab image, the resultant composite is a noisy scene. The signals (i.e., new map features and deletions) are not readily apparent to the compiler simply because there is too much for the eye to see.

Although the scale of the map and photograph are the same, the map representation had been symbolized; for example, roads had been deliberately drawn wider than their ground dimensions and their alinements had been generalized. When lack of coincidence was observed, it was difficult to determine whether it was caused by actual change or by displacements due to cartographic license. Because of the difficulty of identifying areas of

legitimate change between map and photograph, another approach was used.

Skylab Revision Compilation

A clear transparent overlay (in place of the map overlay) was placed over the enlarged S-190A photograph. All transportation systems (major roads, railroads, bridges, airfields, power lines, and pipe lines) were monoscopically compiled as single-line features from the photographs.

Roll 20 (B&W IR 0.8 to 0.9 μm) was used for a separate compilation of open water directly onto the map overlay. Water features were sharply imaged, and the land-water interface, where change had occurred, was compiled with confidence. The near IR photographs uniquely imaged and defined open-water features, but narrow water features that would be symbolized as single lines could not be seen.

After the culture features and open-water features had been extracted separately, the two overlays were separately registered to the obsolete map overlay. The compiler then had a map from Skylab of features that could be compiled. Not all had undergone change. The pencil tracing of the compilation was enhanced with ink, most nonrelevant map features were eliminated, and revision features were noted.

DISCUSSION OF RESULTS

Revision results at 1:250,000 scale

By the method described, a portion of the Baltimore 1:250,000-scale quadrangle was revised from one S-190A frame. The result was a color composite consisting of the base map printed in blue, the revised water features in red, and the revised cultural features in black. The cartographic process was not carried through to normal completion (fig. 2).

The land-water interface of the upper Chesapeake Bay shows subtle changes that indicate the value of Skylab data for compiling open-water features. The changes are attributed to actual changes in the shoreline and the geometric fidelity of Skylab as compared to the 1:250,000 map, which is a mosaic composite. Several reservoirs were compiled from Skylab imagery with more delicate detail of meanders than on the original map, and a few new ponds were noted. But the upland drainage pattern consisting of myriad streams was lost in Skylab imagery.

Changes in transportation systems can be seen in Skylab imagery, and although highway interchanges are not compiled at 1:250,000 scale, it is worth noting that they can be compiled from Skylab S-190A photographs.

In many places the Skylab photographs indicated that a second road had been added alongside an established road to make a dual highway. Although the position of the old road was not always clear, most of the major transportation systems could be mapped from S-190A. In general, the correspondence is good between cultural detail on the base map and the Skylab revision photographs.

Revision results at 1:1,000,000 scale

A portion of the Chesapeake 1:1,000,000-scale IMW quadrangle was revised from 3 S-190A frames. The result was a color composite consisting of the base map printed in blue, the water-feature revisions in red, and the revised cultural features in black. Again the compilation was not carried through to a finished map (fig. 3).

CONCLUSIONS

S-190A

S-190A imagery at 1:1,000,000 and enlarged to 1:250,000 scale can be used for limited revision. Following are the map features that can generally be compiled or revised from S-190A imagery:

1. Interstate highways, including most intersections
2. Major airports
3. Certain secondary roads, depending on their spectral characteristics
4. Long-running pipelines under ideal conditions of contrast
5. Most major road systems (U.S. and State roads). Most often if a road or railroad has been in existence for

some time, its presence can be detected but complete information on its characteristics cannot always be interpreted.

6. Open-water bodies and major rivers
7. New housing subdivisions

Certain critical features that are mapped on USGS 1:250,000-scale quadrangles could not be seen: secondary roads, city limits, the traces of major highways through cities, railroads (sometimes mistaken for pipelines and conversely), and the drainage network.

The black-and-white infrared photographs are very useful for mapping open-water features. Color images were not used. Cost benefits of the color enlargements are not proportionate to their photointerpretative value.

The orbital configuration and the general inability to photo-interpret many required features with confidence prevent USGS from considering Skylab data as input material for revision of small-scale maps. In underdeveloped areas of the world, where no other data are available, a base map at 1:250,000 scale of major transportation features and open water bodies could be compiled. Other data sources of higher precision would be required to complete the map.

S-190B

The value of S-190B data applied in the same manner as the S-190A data is obvious. There is no point in demonstrating the superiority of a camera with an 18-inch focal length over one with a 6-inch focal length for identical mapping tasks.

USGS is only now beginning to compile a 1:100,000-scale map series. S-190B photographs of a local area were examined in a stereoplotter (Kelsh and Kern PG 2) to attempt basic compilation of this scale. Without exception, those evaluating the data stated that they could not compile all the required features even though they knew the area. As with S-190A, most of the major road nets and transportation systems could be compiled but not in their entirety. Long-established secondary roads were impossible to follow. The attempt to compile a 1:100,000-scale map was therefore abandoned.

ADJUNCT EXPERIMENT

S-190B Overprint

Western Mapping Center of USGS conducted an independent experiment to use S-190B imagery in conjunction with operational 1:100,000-scale compilation. A single frame of SO-242 color film was enlarged 10X in two stages and overprinted on the Sonoma County, Calif., line map. The result is a composite line map and photograph printed in monocolor (fig. 4). In this instance, the Skylab photograph was more recent than the compilation photographs, and evidence of new roads and housing developments

could be seen. Skylab imagery could serve, at 10X enlargement, as a limited revision source for updating major features on a 1:100,000-scale map.

Aerotriangulation experiment

A strip of S-190B photographs covering an area from Clovis, N.M., to San Angelo, Tex., (300 miles) was set and digitized on a Wild A 7 stereoplotter. Ten models were oriented for this aerotriangulation experiment. Relative orientation was difficult due to residual parallax probably caused by the bidirectional shutter of the ETC. Residual distortions in the wing ties (pass points to adjacent models) averaged 300 feet. Three horizontal map points were used to hold the strip--one at each end and one in the middle. Nine vertical points (elevations) obtained from topographic maps were also used as constraints.

The horizontal root-mean-square error (RMSE) on unrestrained points was 316.5 feet, and the vertical RMSE was 471.9 feet.

Photographic data generating errors of this magnitude cannot be used for maps that must meet National Map Accuracy Standards. The standards require that of all well-defined points tested, not more than 10 percent shall be in error more than 0.02 inch.

SUMMARY

The purpose of this experiment was to determine if S-190 photographs from the Earth Resources Experiment Package aboard Skylab could be used to revise small-scale maps in the United States. Five experiment sites (fig. 1) were designated, separated geographically so that photographs of alternative sites could be obtained despite adverse weather and to provide diversity of mapping conditions.

S-190A film positives for all five experiment sites were received from NASA. A best-fit comparison of enlarged photographs with maps at scales 1:1,000,000 and 1:250,000 showed that the S-190A photographs at scale 1:2,850,000 can be enlarged to meet geometric requirements for revision of maps at 1:1,000,000 scale and of selected features at 1:250,000. Enlargements to 1:250,000 scale allow only limited identification of such cultural features as railroads, secondary roads, and the limits of urban areas. Features related to topography, such as small streams, are not visible for compilation. The disproportionate base/height ratio of the photographs precluded topographic mapping. Limited revision of a portion of the Chesapeake IMW quadrangle, scale 1:1,000,000, and the Baltimore 1:250,000-scale map was attempted. Major roads, airports, and open-water features can be compiled from Skylab photographs at 1:250,000 scale.

S-190B photographs were used in an experiment of extending horizontal control by analytical photogrammetry 300 miles across Texas and as a photoimage overprint for an experimental 1:100,000-scale county map in California. The horizontal and vertical errors were excessive for 1:250,000 scale. The photoimage overprint serves as a complement to the line map, supplying information as current as the photographs.

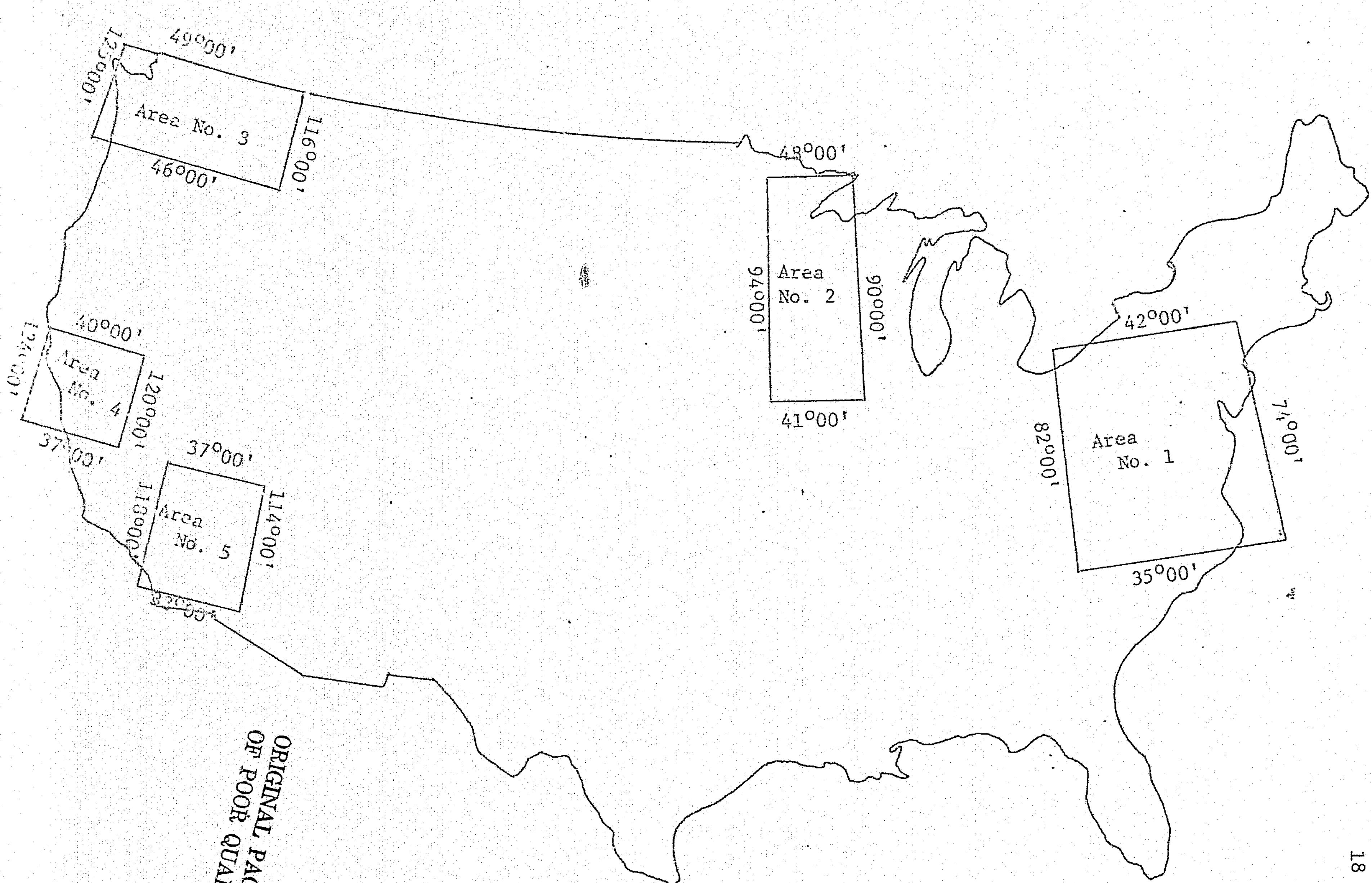

Figure 1 Experiment Sites

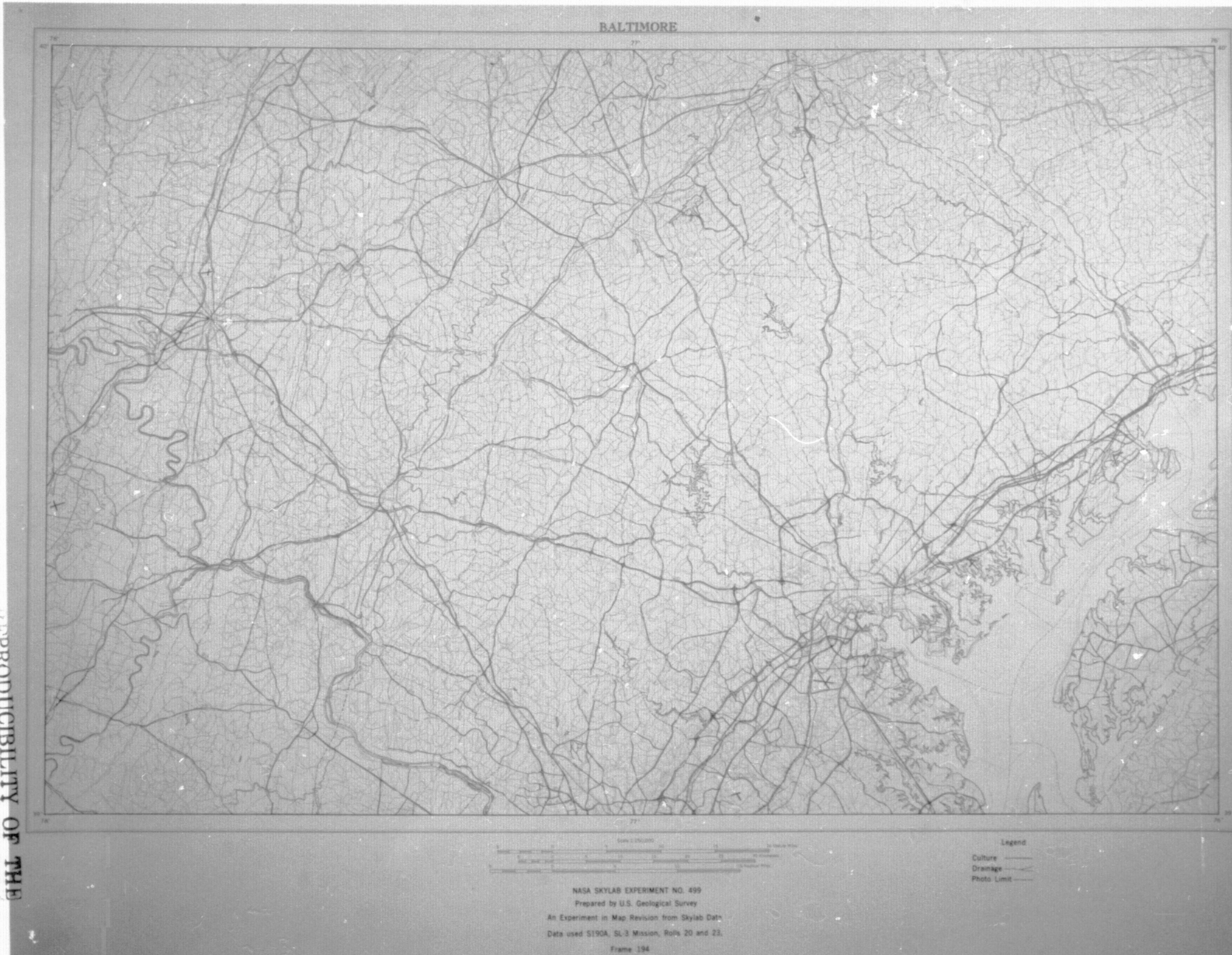

Figure 2 (1:250,000)

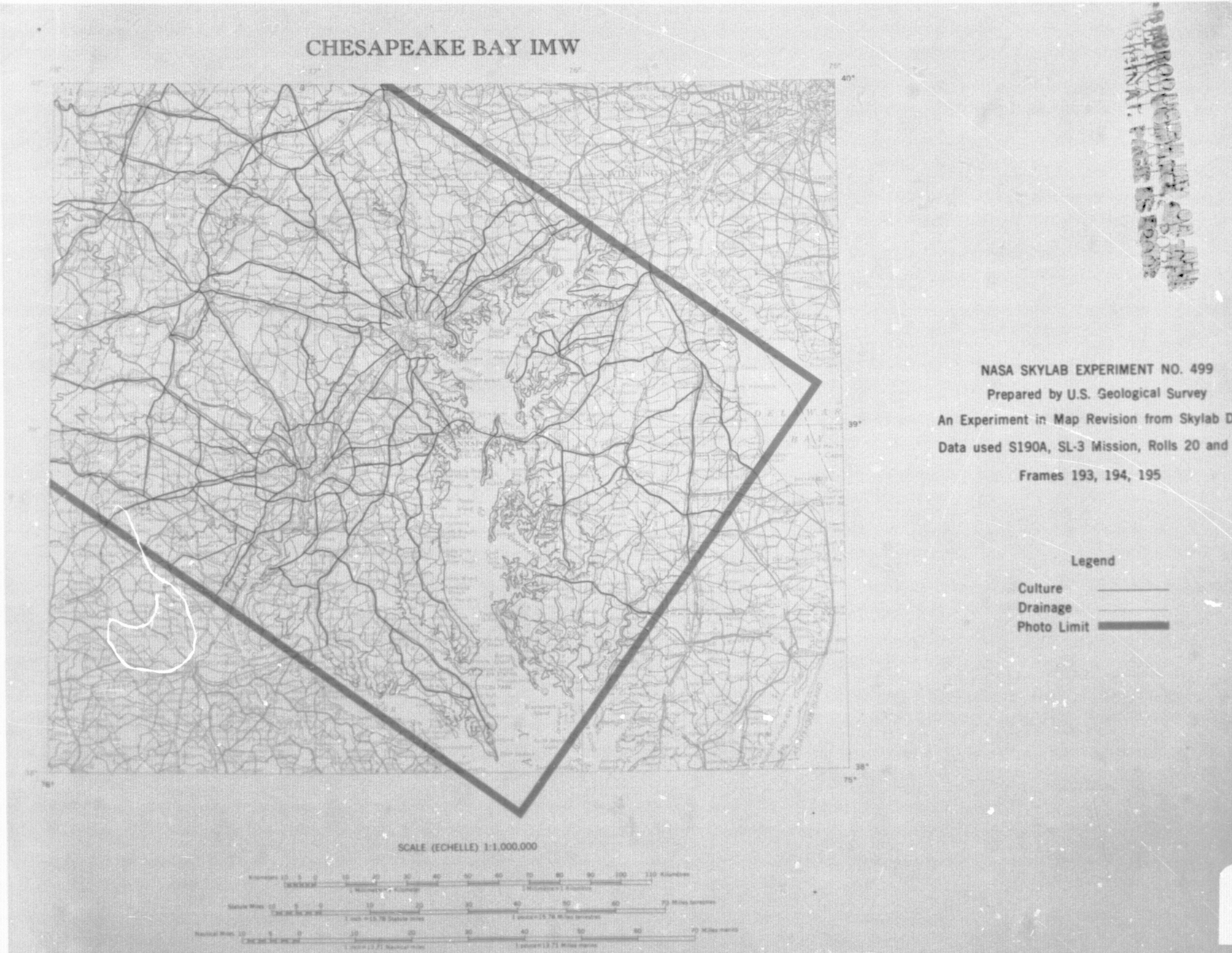

Figure 3 (1:1,000,000)

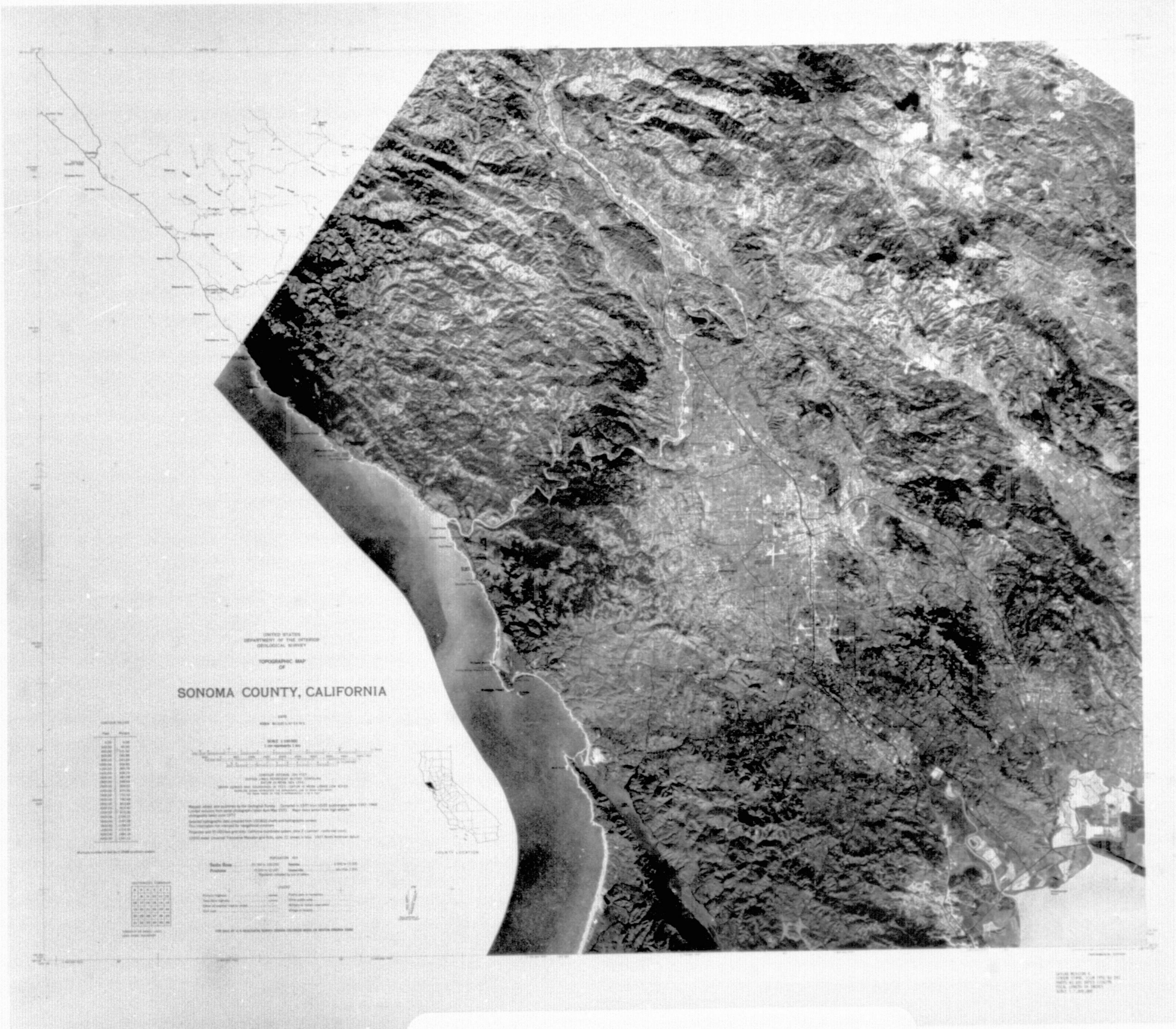

Figure 4 (S-190B Overprint)
Reduced for publication

Table 1 Multispectral Camera Station Characteristics and Film Rolls Used

Sta	Filter	Filter Bandpass, micrometer	Film Type*	Estimated Ground Resolution††, feet (meters)	Mission & Roll No.		
					SL-2†	SL-3	SL-4
1	CC	0.7 – 0.8	EK 2424 (B&W infrared)	240 – 260 (73 – 79)	01‡,07,13	19,25,31, 37,43	49§,55,61, 67,73,A1,1B
2	DD	0.8 – 0.9	EK 2424 (B&W infrared)	240 – 260 (73 – 79)	02,08,14	20,26,32, 38,44	50§,56,62, 68,74,A2,2B
3	EE	0.5 – 0.88	EK 2443 (color infrared)	240 – 260 (73 – 79)	03,09,15	21,27,33, 39,45	51§,57,63, 69,75,A3,3B
4	FF	0.4 – 0.7	SO-356 (hi-resolution color)	130 – 150 (40 – 46)	04,10,16	22,28,34, 40,46	52§,58,64,70 76,A4,4B
5	BB	0.6 – 0.7	SO-022 (PANATOMIC-X B&W)	100 – 125 (30 – 38)	05,11,17	23,29,35, 41,47	53§,59,65, 71,77,A5,5B
6	AA	0.5 – 0.6	SO-022 (PANATOMIC-X B&W)	130 – 150 (40 – 46)	06,12,18	24,30,36, 42,48	54§,60,66, 72,78,A6,6B

* Eastman Kodak Company
† SL-1 was the launch of Skylab without crew.
†† At low contrast
‡ Note that all roll numbers are 2-digit numbers. Single-digit numbers were used in other cameras.
§ Without filter

Table 3. Earth Terrain Camera Film Characteristics and Rolls Used

Film Type*	Wratten Filter	Filter Bandpass, micrometer	Estimated Ground Resolution††, feet (meters)	Mission & Roll No.		
				SL-2	SL-3	SL-4
SO-242 (hi-resolution color)	none	0.4 – 0.7	70 (21)	81	83,84, 86,88	90,91, 92,94
EK 3414 (hi-definition B&W)	12†	0.5 – 0.7	55 (17)	82	85	89
EK 3443 (SL-2 & SL-3) (infrared color)	12	0.5 – 0.88	100 (30)	–	87	–
SO-131 (SL-4) (hi-resolution infrared color)	12	0.5 – 0.88	75 (23)	–	–	93

* Eastman Kodak Company
† "Minus blue" filter
†† at low contrast

Figure 5

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